than one genus; but, in absence of sufficient knowledge of the skull to establish differences, the four species are referred to a new genus, *Diademodon*. Its hinder molar teeth have undivided roots, and low crowns, which are subquadrate or transversely ovate, surrounded by a diadem of low cusps, which are chiefly developed on the external and internal borders, with crenulations or minute cusps on the anterior and posterior margins of these teeth. There is a low central cusp in the middle of the crown from which slight ridges extend, chiefly in the transverse direction; but in the type species these ridges take the form of a cross. The species are distinguished by the form of the crown and the details of the cusps. The upper and lower teeth are opposed so as to be evenly worn, but the mandibular teeth are narrower.

These teeth are highly specialised, but distinct in plan from *Tritylodon*, and from all known Reptiles. They closely approximate to some of the higher Mammalia. The author refers *Diademodon* to a division of the Theriodontia in which the teeth become worn with use, which is named Gomphodontia.

VIII. "On the Effect of Magnetisation upon the Dimensions of Wires and Rings of Annealed Iron." By Shelford Bidwell, M.A., LL.B., F.R.S. Received February 14, 1894.

In the year 1885 I submitted to the Royal Society the first of a series of papers* upon the changes produced by magnetisation in the dimensions of rods, &c., of iron and other magnetic metals. The chief, and perhaps the most interesting, subject of the paper was the observation that if the magnetising force were sufficiently increased, the extension which a magnetised iron rod at first underwent (as originally noticed by Joule†) was followed by contraction, the rod ultimately becoming shorter than when it was unmagnetised. The elongation was generally found to attain a maximum with a magnetising force of from 80 to 120 C.G.S. units, and to vanish with a force of 300 to 400, retraction occurring when still higher forces were applied.

From that date until quite recently no accounts of similar experiments by other workers have, so far as I know, been published. About the beginning of last year, however, it was stated in the scientific journals that M. Alphonse Berget had investigated the magnetic dilatation of iron in strong fields, and had found that the length of his bar was still increasing when the magnetic field had

* 'Roy. Soc. Proc.,' vol. 40 (1886), pp. 109, 257; vol. 43 (1888), p. 407; vol. 47 (1890), p. 469; vol. 51 (1892), p. 495. 'Phil. Trans.,' vol. 179, A (1888), p. 205.

† Joule's 'Scientific Papers,' pp. 48 and 235.

reached as high a value as 540 units, beyond which point the experiment was not carried.

On reference to the original paper in the 'Comptes Rendus,'* it appeared that the experiment was made with a cylindrical bar, measuring 5·2 cm. by 1·95 cm., its length being less than three times its diameter. The actual magnetising force must therefore have been enormously less than that due to the coil itself, and it is very improbable that it ever reached the value at which the iron (or the greater portion of it, for the magnetisation must have been far from uniform) would attain its maximum extension.

The 'Phil. Mag.' of December, 1893, contains an account of some experiments by Mr. Sidney Lochner, made, as he states, with the express object of determining whether M. Berget's results or my own were correct. Using a thin iron rod, he obtained a curve very closely resembling those published by myself; but, as might have been expected, he found that a short thick rod, like that of M. Berget, gave no decided indication of having passed a maximum extension within the limits of the magnetising force that he employed.

A paper of great interest, on "Hysteresis attending the Change of Length by Magnetisation in Nickel and Iron," by Mr. H. Nagaoka, published in the 'Phil. Mag.' for last January, also incidentally confirms my observations.

In subsequent papers I have shown how the elongations and retractions were modified by tension, and by the passage of electric currents through the specimens under examination; and in the present communication I propose to deal with the somewhat unexpected effects which were produced by carefully annealing the iron before using it.

Upon this point, Joule's observations are as follows:—"On inspecting the tables, it will be remarked that the elongation is, for the same magnetic intensity, greater in proportion to the softness of the metal. It is greatest of all in the well annealed iron bars, and least in the hardened." †

The current belief, in which till quite recently I myself shared, is in accord with this statement. It appears, however, as will be shown, that it represents the reverse of the truth. Joule's conclusion with regard to iron seems to have been based entirely upon the results of a single experiment with an unannealed bar, and he may possibly have been mistaken in supposing that it consisted of the same quality of iron as the annealed bars which he had used before.

My own experiments, the results of which are given in Table I and fig. 1, were made with a piece of iron wire, 10·6 cm. in effective length and 0·265 cm. in diameter. The curve marked (1) shows the behaviour of the iron in the condition in which it was bought. Its

* 'Comptes Rendus,' November 7, 1892, p. 722.

† Joule's 'Works,' p. 246.

length increased rapidly with the magnetising force, the maximum increment which was obtained in a field (due to the coil) of about 140 units being as much as 45 ten-millionths of the length of the wire. The same wire was then carefully annealed, and the experiment repeated, with the results indicated in curve (2). It will be seen that the maximum increment had fallen from 45 to about 8 ten-millionths—less than one-fifth of its former value—and was reached with a force of about 60 units. Finally, the wire was raised to a bright red heat in a blowpipe flame, and dropped into cold water, its subsequent performance being as indicated in curve (3). This last operation was found to have raised the maximum elongation from 8 to 25 ten-millionths, while the corresponding magnetising force had increased from 60 to about 110 units.

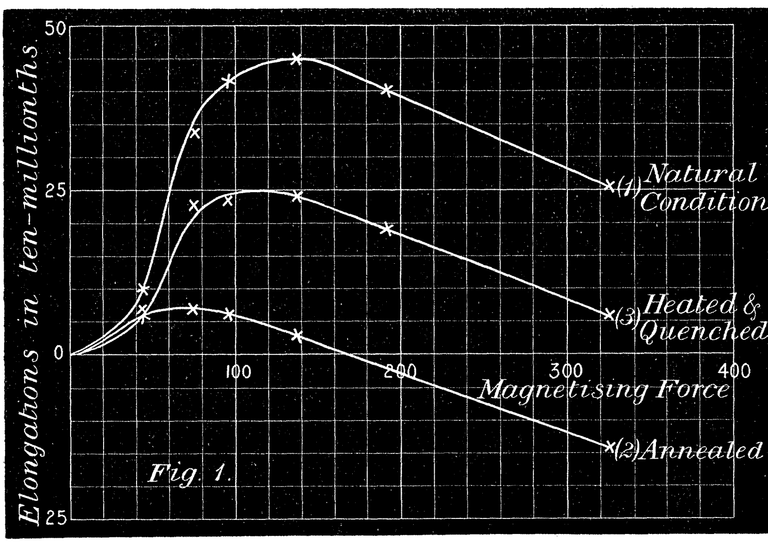


Fig. 1.

Table I.

Magnetising force C.G.S. units.	Elongations in ten-millionths of length.		
	Iron as bought (1).	Annealed (2).	Made red hot and quenched (3).
43	10	7·0	6
74	34	7·0	23
96	42	6·0	24
138	45	3·5	24
192	40	− 1·2	19
324	25	−17·0	6

Other experiments gave results of a similar character, and many attempts were made to obtain an annealed wire which would not be lengthened at all by magnetisation, but begin to contract from the first, like nickel and cobalt. But I never succeeded in bringing a wire into such a condition that its maximum elongation was less than 7 or 8 ten-millionths.

Though I failed with straight wires, however, I was perfectly successful with an iron ring.

I have in a former paper given an account of some experiments made with rings.* The changes in the diameter of a ring were found to be of just the same character as those observed in straight rods. With a continuously increasing magnetising force the diameter first increased in length, and, after passing a maximum, ultimately became shorter than at starting.

In those experiments three different rings were employed, not one of which had been annealed before being used; I therefore had a new ring made of good soft iron, and very thoroughly annealed. It was afterwards fitted with a boxwood jacket, around which 515 turns of insulated wire were wound in the usual way. With this ring it was found that the smallest currents which caused any effect at all produced contraction; there was no indication of the smallest preliminary extension.

The results of an experiment with the ring (which I shall call Ring I) are given in Table II and in the lower curve of fig. 2. The latter bears a close resemblance to the earlier portion of the curve given by a rod of cobalt. The greatest retraction reached was nearly 75 ten-millionths (exceeding any that has been ever before obtained with iron), and from the appearance of the curve there is reason to believe that this was still far from its limiting value, but the heating effect of the magnetising current made it impossible to carry the experiment further.

* 'Phil. Trans.,' 179, A, p. 205. A ring is prepared for the experiment in the following manner:—Short brass rods are attached to it at opposite ends of a diameter, forming prolongations, which serve to transmit the effect of changes in the length of the diameter to the measuring instrument. The ring is then covered with a loosely fitting boxwood jacket, also ring-shaped, and through holes in this the two brass rods protrude. The magnetising coil is wound directly upon the wooden ring, the object of the latter being to protect the iron from the heat generated when a current is passing through the coil.

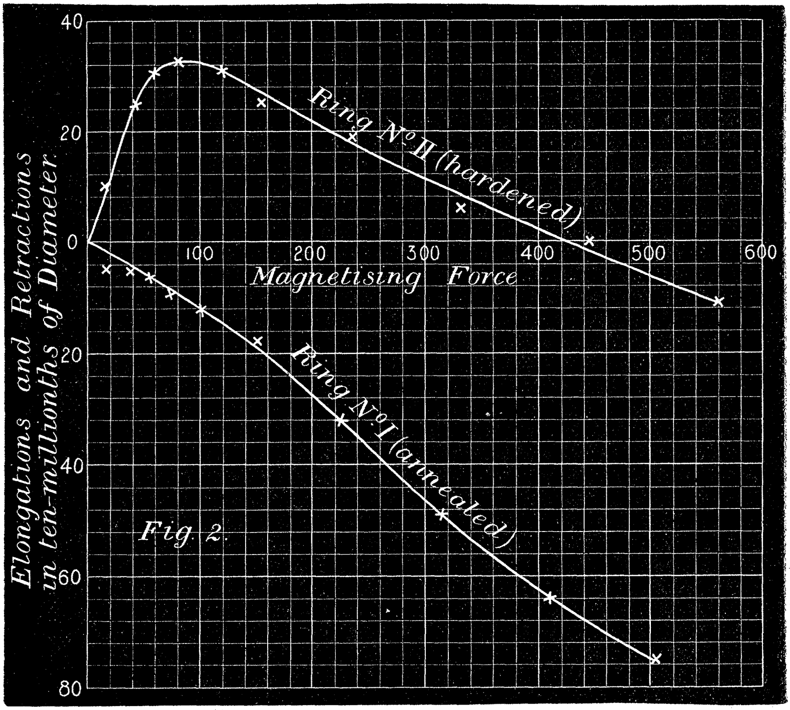


Fig. 2.

Table II.

Ring I (annealed).		Ring II (hardened).	
Magnetising force C.G.S. units.	Elongations in ten-millionths of length.	Magnetising force C.G.S. units.	Elongations in ten-millionths of length.
15	− 4·5	15	10
39	− 5·6	42	25
56	− 6·2	61	31
73	− 9	81	33
101	−12	119	31
152	−18	155	25
226	−32	239	19
312	−49	328	6
410	−64	445	0
506	−75	560	−11

I at first contemplated unwinding the wire, hardening the iron, and repeating the experiment with the same ring; but felt unwilling to

run the risk of spoiling so remarkable a specimen which it might turn out to be difficult or impossible to replace. I therefore had another ring made of iron from the same parcel, and believed to have been cut from the same bar as the first. As, however, there was some doubt about this latter point, I thought it better in the first instance to anneal the new ring, and test it with a few turns of wire wound upon it. Its behaviour was found not to differ materially from that of Ring I. A very small elongation—too small to be measurable—was, however, observed with a magnetising force of only 3 C.G.S. units, contraction beginning when the force was increased beyond this value. The ring was then made red hot, and plunged into cold water, with the object of hardening it, after which operation it was replaced in its boxwood jacket and wound with 473 convolutions of wire.

This ring, called Ring II, was now found to give the same results as the old unannealed rings and straight wires. As appears in Table II and fig. 2, it attained its maximum elongation of about 33 ten-millionths in a field of 80, its original length was recovered in a field of about 440, and a retraction of 11 ten-millionths occurred in a field of 560.

It appears, therefore, that as regards magnetic changes of dimensions, an iron rod or ring is affected by annealing in very nearly the same manner as by tensile stress,* a result which would hardly have been anticipated.†

Notes regarding Details.

The apparatus and methods of experiment were the same as those fully described in 'Phil. Trans.,' vol. 179, A, pp. 218—224, the instrument being arranged so as to have a magnifying power of 43,745.

The height of each little square in fig. 2 corresponds to a length of about one-millionth of an inch (0·00000088 in. for Ring I and 0·00000103 in. for Ring II).

The wires and rings were demagnetised by reversals before every single observation. For a description and diagram of the demagnetising apparatus, see *loc. cit.*, p. 207.

* 'Roy. Soc. Proc.,' vol. 47 (1890), p. 469.

† The less so since the length of an iron rod seems to be diminished by annealing. A piece of iron wire 100 mm. long, cut from the same hank as that used in the experiments, was heated in a Bunsen flame, and slowly cooled. It was found to have contracted 0·07 mm., *i.e.*, 0·07 per cent. It was then heated in the blowpipe flame, and dropped into cold water. This produced an elongation of about 0·02 mm., leaving the wire 0·05 mm. shorter than it was originally. These measurements were made with a rough apparatus extemporised for the purpose, and I do not attach much importance to the quantitative results, though there can be little doubt that they are qualitatively correct.

The dimensions of the iron rings and their boxwood jackets were as follows :—

	Ring I.	Ring II.
Rings—		
External diameter......	6·9 cm.	6·1 cm.
Width................	2·9 ,,	3·0 ,,
Thickness	0·4 ,,	0·35 ,,
Mean radius	3·25 ,,	2·82 ,,
Boxwood jackets—		
External diameter......	7·7 ,,	6·9 ,,
Width................	3·7 ,,	3·8 ,,
Thickness	1·3 ,,	1·15 ,,
Convolutions	515	473
Gauge of wire	0·91 mm.	0·91 mm.

The rings were formed from rectangular bars with welded joints, and were turned in the lathe to the above dimensions.

The magnetic fields were calculated from the formula $H = 2ni/r$ where n is the number of convolutions, i the C.G.S. current, and r the mean radius.

The current was derived from a battery of twenty-seven storage cells used for lighting the house.

IX. "On Correlation of certain External Parts of *Palæmon serratus*." By H. THOMPSON. Communicated by Professor WELDON, F.R.S. Received January 25, 1894.

In 1890 Professor Weldon published ('Roy. Soc. Proc.,' vol. 47, p. 445) the results of measurements of certain organs of the common shrimp, with a view to establish by accurate data the degree of variation existing in those organs. In a later paper ('Roy. Soc. Proc.,' vol. 51, p. 2) he determined, by Mr. Galton's method there described, the degree of correlation existing between four organs of the same animal, and in a recent paper ('Roy. Soc. Proc.,' vol. 54, p. 318) similar determinations have been worked out by him for certain organs of *Carcinus mœnas.*

Some time ago it was suggested to me by Professor Weldon that I should determine the values of correlated variations in a number of parts of the hard exoskeleton of the common prawn (*Palæmon serratus*). Accordingly, 1000 adult female prawns, chosen at random, were procured from Plymouth and measured. Twenty-two measurements were made of each prawn, except in the case of two or three measurements which were made on part only of the sample.

The parts measured were the following :—

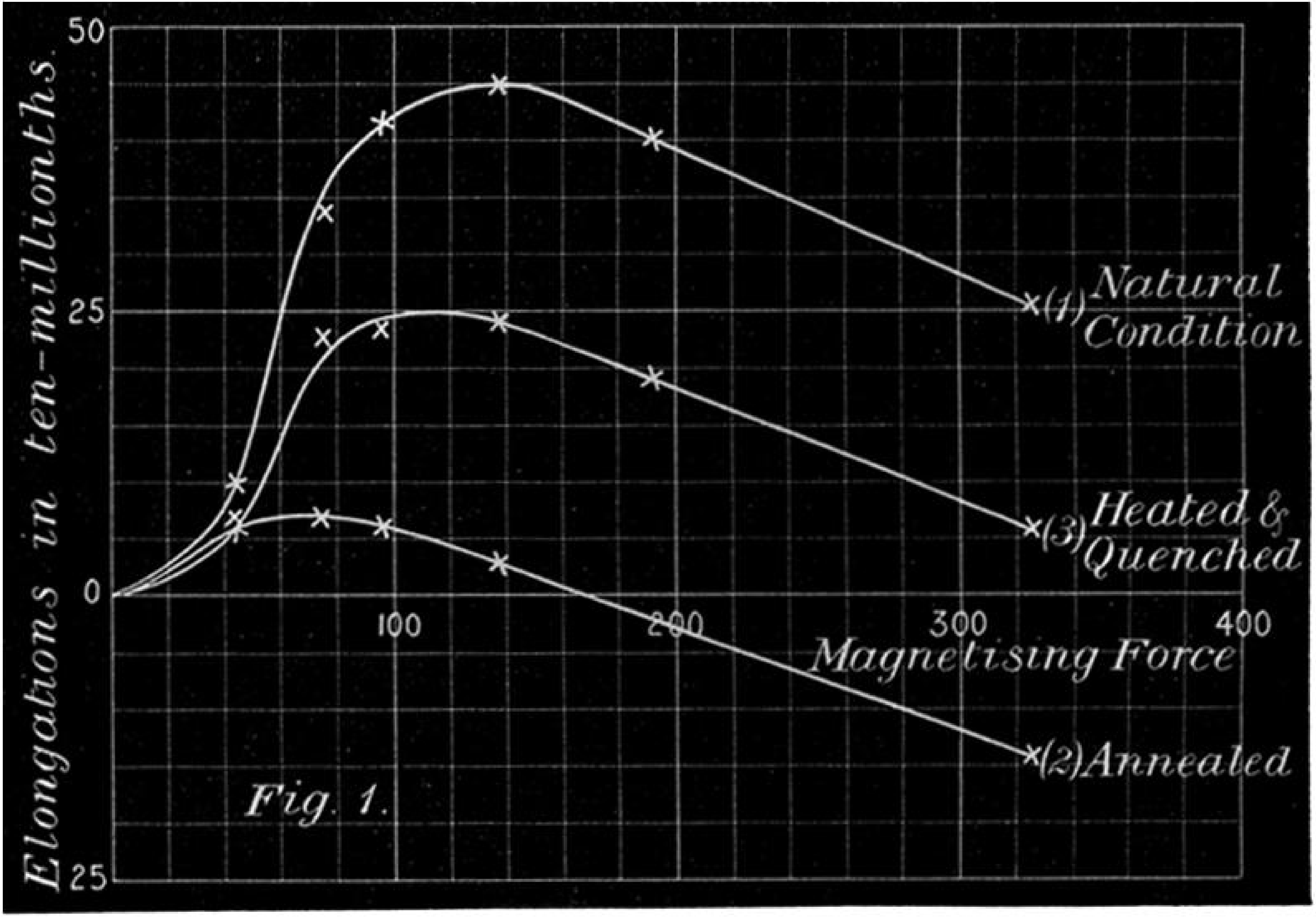
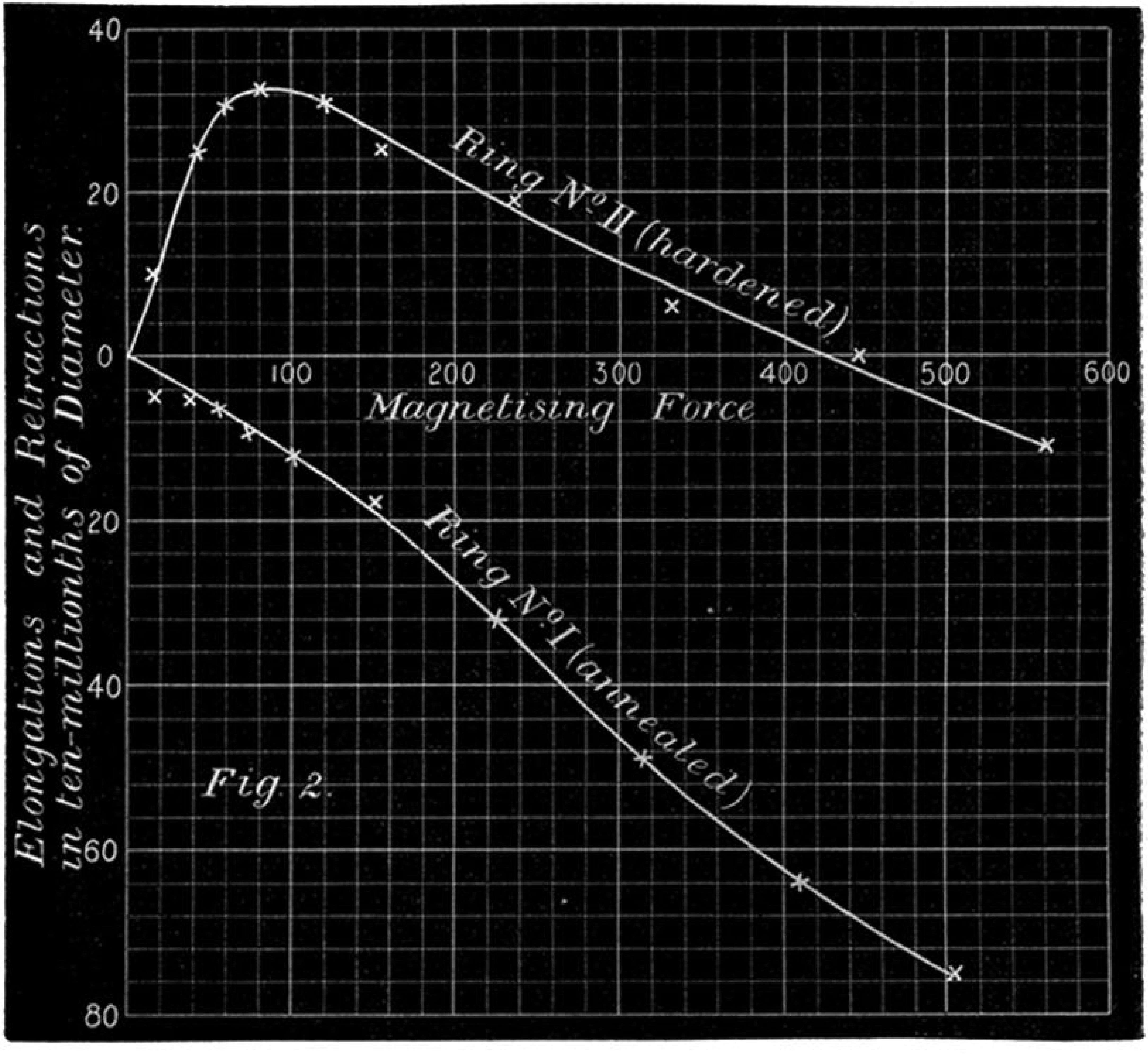

Elongations in ten-millionths.
50
25
0
25
100
200
300
400
Magnetising Force
(1) Natural Condition
(3) Heated & Quenched
(2) Annealed

Fig. 1.



Elongations and Retractions
in ten-millionths of Diameter.
40
20
0
20
40
60
80
100
200
300
400
500
600
Magnetising Force
Ring N°II (hardened)
Ring N°I (annealed)

Fig. 2.